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Qualitative Simulation and Intelligent Tutoring Aids for Training in the Operation of Complex Dynamic Systems

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Progress report for June 1987 - May 1988

In this report we describe the progress of our research on the development of an intelligent tutoring system for the marine power plant simulator that we had designed and implemented during the previous ONR contract. The simulator, implemented in Interlisp-D, runs on Xerox 1100 series of Lisp machines. Under the current ONR contract, we have three major objectives: 1) to develop an architecture for intelligent tutoring systems for diagnostic problem solving in the supervisory control operation of complex dynamic systems; 2) to implement the tutor for the marine power plant simulator; and 3) to develop and evaluate a training program using the tutor implementation. During the first year of the project, a number of subgoals were identified to accomplish our objectives. The subgoals and the progress during this period are described below.

When the contract started in June 1987, Vijay Vasandani, a doctoral student with backgrounds in mechanical, industrial, and systems engineering, joined the project. Our immediate goal was to help him become proficient with the details of the simulation so that he can contribute to the objectives of the project. Even though he has had some practical experience with steam power plants, the complexity of the steam power plant simulation and his lack of familiarity with the marine power plant domain and LISP, necessitated the need to devote a large amount of time to familiarize him with the principles and implementation details of the simulation and the overall nature of the project. In addition to learning INTERLISP and the operation of the Xerox 1109 Lisp machine, we spent time on the details of how the qualitative approximation technique is implemented in developing the power plant simulator.

While learning INTERLISP and the details of the simulation, Vasandani also conducted a literature survey to become familiar with the state of the art in knowledge structures and control strategies presently being used in tutoring and training systems. This exercise contributed to the understanding of the domain better and enabled the assessment of the degree of difficulty and complexity associated with the domain in relation to that exhibited by other tutoring and training domains.

In the months following the initial familiarization, a small scale preliminary model of expert's fault diagnosis task was developed. This model was based on ideas proposed in an earlier study conducted during our previous ONR contract where data and protocols were collected from experts performing the troubleshooting task on the simulator of the marine power plant. Relevant information about two common modes of failure for a single component were compiled into frames which constitute our choice of knowledge base for representing failure knowledge. Given the

obvious symptoms of failure, a control strategy has been designed to first identify frame or frames that provide a plausible explanation for the symptoms. Information contained in the failure frames and the symptoms is used to proceed with the task in a fashion typical of any forward chaining process. The process represents some of the flavors of schema instantiation, generate and test paradigms, and symptomatic search strategies adopted by experts to diagnose a complex dynamic system. This approach is expected to facilitate upgrading of the model by extending its fault detection capabilities to include other failures with the incorporation of new failure frames. An abstract based on this work was submitted to a conference[§] and has been accepted for presentation. A paper describing the details of the work is under preparation and will be completed in August 1988.

In addition to the educational efforts concerning the simulation details, we began converting the simulation into Common Lisp, first on the Xerox Lisp machines and then on Apple Macintosh II computers (Allegro Common Lisp). This translation to Common Lisp became necessary since the anticipated computational needs of the simulator and the tutoring system exceeds the capabilities of the D-machines. Also, translation to Common Lisp on a personal computer/workstation at this time appears to provide the best opportunity because of Xerox's decision to leave the workstation market and the possibility to complete the conversion while the new students are still in the process of learning the principles and implementation details of the simulation. Porting the simulator to the Macintosh environment at this time has the advantage of enabling the students become fully familiar with the project while affording us the opportunity to develop a more robust and versatile version of the simulator.

We have completed rewriting major portions of the code for the simulation using objects in the Common Lisp Object System (CLOS). The primitives that form the basis for the simulation have been implemented as objects. The manner in which the system states and connectivity of components are represented and the states are propagated has been improved considerably by the use of objects. In addition, the Interlisp-independent functions have been translated for the ACTIVEREGIONS package needed for the direct manipulation, graphical interface.

As a result of the conversions and updates, we now have code that is more modular and hence easier to maintain. This should enable us to more easily implement and incorporate the tutor. Also, new users can become conversant with the simulation in less time than in the previous version. Redoing

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the simulation in CLOS has already improved the efficiency and effectiveness with which changes can be introduced as the program evolves.

In addition to his efforts to understand the details of the simulation, participation in the porting and translation of the simulation from Interlisp-D to Common Lisp, and implementation of portions of the code in CLOS, Vasandani has been working on developing control interfaces into the simulation. The original simulation was not designed to handle operator inputs that altered the state or the configuration of any of the components. In the version of the simulation under development, this will be changed so that an operator can open and close valves, change the operating conditions, etc.

A considerable amount of effort during the first year was spent in bringing new students up to speed on the details of the simulation. While we had hoped to complete the translation into Common Lisp by the end of the first year and have the program running on the Mac II, the complexity of the dynamic system operation and the simulation details have resulted in the need to invest a large amount of time in training new students. We have managed to involve a doctoral student (Vasandani) who is now familiar with the details of the simulation and complete a major portion of the simulation. Even with a background in mechanical engineering, including some experience with steam power plants, it has taken Vasandani more than three quarters to become familiar with the details of the simulation and system operation. Due to the nature of the problems and the level of difficulty, it seems inevitable that a large portion of time needs to be spent in maintaining the simulation.

Progress was also hampered by the difficulty of finding qualified students capable of understanding the complexity of dynamic systems such as power plants. For instance, a master's student, Lauren Weisberg, joined the project during the second quarter. While she had some experience with Common Lisp, she lacked any experience with power plants or other complex dynamic systems. After spending three quarters on the project learning the basics of the simulation, during which period she participated in the translation effort, she decided not to pursue a thesis and hence left the project. The newer version of the simulation running on Apple Macintosh II computers is expected to help attract and retain capable students to work on various aspects of the project.

We plan to complete the simulation by the end of September 1988. Designs for an intelligent tutor are already being planned. A preliminary version of the tutor should be ready by the end of November. After pilot experiments during December 1988 - January 1989, we plan to start conducting experiments in March 1989.